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1 **Seeking the Sun in Deep, Dark Places: Mesopelagic Sightings of Ocean**

2 **Sunfishes (Family Molidae)**

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13 Evidence is presented from publicly available remotely operated vehicle (ROV) footage
14 that suggests deep water ranging in ocean sunfishes (family Molidae) is more common than
15 typically thought, including a new maximum depth recorded for the southern sunfish (*Mola*
16 *ramsayi*).

17 Keywords: Diving Behaviour, Foraging, *Mola mola*, Remotely Operated Vehicle, SERPENT
18 Project.

19 Running Head: Mesopelagic Sunfish Sightings

The family Molidae, or the ocean sunfishes, is currently believed to comprise four widely distributed species: the ocean sunfish *Mola mola*, (Linnaeus, 1758), sharptail sunfish *Masturus lanceolatus* (Liénard, 1840), southern sunfish *Mola ramsayi* (Giglioli, 1883) and slender sunfish *Ranzania laevis* (Pennant, 1776), although the taxonomy remains uncertain, with the possible existence of several currently undescribed species (Bass *et al.*, 2005; for review see Pope *et al.*, 2010). Often seen basking at the surface, there was a long held perception that these species were rare, inactive drifters feeding solely on gelatinous zooplankton (see Pope *et al.*, 2010 for review). However, an increasing number of recent studies have shown these notions to be far from accurate, with evidence of long distance migrants travelling ca. 27 km day⁻¹ (Cartamil & Lowe, 2004), displaying deep diving behaviours (Sims *et al.*, 2009; Hays *et al.*, 2009) and consuming a mixed diet (Syväranta *et al.*, 2012; Nakamura & Sato, 2014). More specifically, there is now strong evidence of cryptic benthivory in these typically pelagic fishes (Harrod *et al.*, 2013) and records of deep water forays to feed on colonial gelata such as siphonophores (Nakamura & Sato, 2014; Nakamura *et al.*, 2015). Taken together, a picture of an active migrant feeding broadly within marine food webs has emerged, but observational data to validate behavioural studies remains difficult to come by (Houghton *et al.*, 2000). Serendipitous sightings of three sunfish species are presented here, sourced from industrial and research submersibles, providing further evidence of the deep ranging capabilities of the Molidae. More broadly, these records taken together with previous ROV sightings of a hammerhead shark (*Sphyrna lewini* (Griffith & Smith, 1834); Moore, S. & Gates, A.,R. *pers. comms.*), add weight to the idea that mesopelagic environments may be of greater importance than thought previously for taxa often considered as epipelagic.

Sightings data were sourced primarily from the SEPRENT project (Jones *et al.*, 2009), which constitutes a scientific partnership using existing industrial technology. As direct observations of marine life in the deep sea are often prohibitively expensive, this collaboration enables scientists to browse video footage shot by industrial ROVs, providing rare access to life in the open ocean and sightings of much understudied species *e.g.* oarfish *Regalecus glesne* (Ascanius, 1772) (Benfield *et al.*, 2013) and deep sea squid *Grimalditeuthis bonplandi* (Verany, 1839) (Hoving *et al.*, 2013). Other data were sourced from ROV footage available online or through personal communications (see Fig. 1 and Table I).

In total, 13 anecdotal sightings of Molidae were obtained at depths of up to 550 m (Table I). Eleven animals were recorded from depths of > 160 m, with eight of these individuals exceeding 200 m. Aside from the general pattern of mid-water ranging the Australian sighting of a *M. ramsayi* at 483 m probably constitutes the deepest record for this species to date. The only previous record of depth use for this species came from the Sea of Oman (Sea & Bejgan, 2014) where an individual was caught in a trawl at 85 m. For context, the maximum depths previously recorded from sunfishes were to 844 m by *M. mola* (Potter & Howell, 2011) and 670 m by *M. lanceolatus* (Harbison & Janssen, 1987), which suggests that 483 m is unlikely to represent a maxima for *M. ramsayi* given the gross morphological similarities between these species.

Previous studies have intimated that such movements of Molidae into deeper water may be a means of locating deep or vertically migrating zooplankton prey (Cartamil & Lowe, 2004; Sims *et al.*, 2009; Dewar *et al.*, 2010; Nakamura *et al.*, 2015). Typically, such forays to depth constitute daytime bouts of V-shaped dives punctuated by periods at the surface (Cartamil & Lowe, 2004; Dewar *et al.*, 2010). Recently, Nakamura *et al.* (2015) verified that the main

function of surfacing is the recovery of body temperature, with the fish increasing heat gain from the warm surface water by physiological regulation [see Hays, (2015) for review]. The data presented here may be aligned with such behaviour given that the greatest depths of sunfish recorded from the ROV footage (Table I) occurred during the day (06:00 – 18:00) but with some diving activity at night (with max. depth of 306 m recorded at 01:30). Such daytime excursions to mesopelagic depths (albeit rarely) have also been documented in leatherback turtles, *Dermochelys coriacea* (Vandelli, 1761), with the overall assertion that individuals were speculating for vertically ascending gelatinous zooplankton, rather than feeding at depth (Houghton *et al.*, 2008). From the ROV footage (Fig. I), no comment can be made on whether these observations constituted brief (i.e. speculative), or prolonged (i.e. feeding) excursions to depth, or the behaviour prior to or following such events. However, these data can provide visual observations over a broad geographical range to support the notion that ocean sunfishes routinely dive below the epipelagic zone.

With respect to prey acquisition at depth, low levels of mesopelagic light suggest that the Molidae possess adequate visual acuity at depth to hunt mobile prey, potentially in combination with other senses such as olfaction, (for review see Hara, 1994). Visual acuity, determined from immature *M. mola*, was calculated at 3.5-4.3 cycles per degree (Kino *et al.*, 2009), similar to values recorded from some adult sharks (e.g. 3.8: *Galeus melastomus* (Rafinesque, 1810), 2.8: *Etmopterus spinax* (Linnaeus, 1758); Bozzano and Collin, 2000) and higher than those from adult cetaceans (e.g. 2.7: *Lagenorhynchus obliquidens* (Gill, 1865), 2.6: *Delphinapterus leucas* (Pallas, 1776); Murayama & Somiya, 1998). As visual acuity typically increases over the lifetime of an individual (Fritsches & Marshall, 2003), this value is likely to increase for mature sunfishes. Eye size usually reflects the importance of vision to

a species (Walls, 1942) and the large eyes of the Molidae support the suggestion by Hays *et al.* (2003) that ambient light levels at prey field depths may be important in determining foraging success in marine predators. Ocean sunfish eyeball diameter data has only been published from juveniles (TL < 1 m), with maximum eye diameter 38 mm (Cleland, 1862). This is comparatively large when considering other pelagic predators (*Caracharodon carcharias* (Linnaeus, 1758); 37.1 mm, *S. lewini*; 25.5 mm: Lisney & Collin, 2007) with the overall inference that Molidae are well adapted to foraging at depth. Moreover, as gelatinous zooplankton may be difficult to locate while looking down through the water column, diving to depth may allow such species to be silhouetted against down-welling light during re-ascent.

Alternatively, prey densities at depth may simply be sufficient to warrant exploration in low-light conditions, although the mechanisms for detection are not yet fully understood. Davenport (1988) and Davenport & Balazs (1991) suggested that the Molidae and leatherback turtles may use luminescence to help in their search for deep prey (*e.g.* pyrosomes): however as such behaviour was not observed here, it is not possible to comment further. The potential for the ROV lights themselves to attract sunfishes must also be acknowledged, given that BRUVs (Baited Remote Underwater Video Systems) routinely employ illumination to entice animals closer to the camera (*e.g.* Fitzpatrick *et al.*, 2013, De Vos *et al.*, 2014, Harvey *et al.*, 2012). This matter aside, gelata are certainly present at depth in open water and can constitute 50-80% of the integrated standing crop by volume (Angel & Pugh, 2000; Houghton *et al.*, 2008). Qualitatively, there is evidence of putative prey in the Gulf of Mexico from the SERPENT archives (corresponding geographically to the 2012 *M. mola* sighting; Table I) including the scyphomedusa *Stygiomedusa gigantean* (Browne, 1910)

113 (Benfield & Graham, 2010), *Aurelia aurita*, (Linnaeus, 1758) narcomedusae (*Solmissus* spp.),
114 salps and ctenophores, suggesting deep water feeding behaviour warrants further
115 investigation.

116 Within this collection of mesopelagic encounters, there was one sighting of specific
117 interest where a *M. lanceolatus* was filmed interacting with the physical structure of the rig
118 itself. Given that the Molidae can be highly parasitised (Fraser-Brunner, 1951) and have
119 been observed undertaking many behaviours suggested to reduce parasite loads (e.g.
120 attracting sea birds; Abe *et al.*, 2012, aggregating at reef cleaning stations and breaching;
121 Konow *et al.*, 2006), the rig structure may offer a hard surface to rub against. In the
122 relatively featureless open ocean, such opportunities are lacking which may explain the
123 behaviour of the 2009 *M. lanceolatus* sighting at 167 m (see Table I: Subsea 2009a). The
124 video footage here clearly shows the *M. lanceolatus* using the platform's framework to
125 scratch itself, suggesting that such structures might provide a service for sunfishes
126 throughout the water column.

127 Another sighting of specific interest was recorded in 2004 to the West of Shetland (Table
128 I). This record was not collected from great depth, but in surface waters, where a *M. mola*
129 was observed at 60°N, close to the reported northerly limit of the *M. mola* range, where
130 they are sighted rarely. This northerly boundary may be temperature constrained as *M.*
131 *mola* in the N.E. Atlantic have been recorded spending 99% of the time in water
132 temperatures between 10-19°C (Sims *et al.*, 2009). Despite its northerly location, this
133 individual was sighted in September when the average sea surface temperature off Shetland
134 is 12.7°C (World Sea Temperatures, 2015), well within the stated *M. mola* temperature

range. Consequently, it is unlikely that the scarcity of *M. mola* sightings in this area reflects thermal tolerances alone.

In conclusion, this paper provides repeated evidence of mid-water ranging in the Molidae using anecdotal sightings from publically available ROV footage. These data suggest that sunfishes are more common in the mesopelagic zone than previously thought, in line with deep water forays of other typically epipelagic species. A new depth record is also presented for the *M. ramsayi* sighted at 483 m and a rare observation of a *M. mola* above 60°N. These data show the importance of collaborations between commercial enterprises and academics, providing access to anecdotal sightings that have the potential to significantly increase the understanding of rarely encountered fish species. Such evidence also serves to highlight that the increasing realisation that the Molidae are far more complex in their ecology than previously thought.

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